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Electrophysiology of facilitation priming in obsessive-compulsive and panic disorders

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Abstract
Objective: Repeated experience with stimuli often primes faster, more efficient neuronal and behavioural responses. Exaggerated repetition priming effects have previously been reported in obsessive-compulsive disorder (OCD), however little is known of their underlying neurobiology or disorder-specificity, hence we investigated these factors. Methods: We examined event-related potentials (ERPs) and behaviour while participants with OCD, panic disorder and healthy controls (20 per group) performed a Go/NoGo task which manipulated target repetition sequences. Results: Both clinical groups showed stronger reaction time (RT) priming than HCs, which in OCD was greater in a checking, than washing, subgroup. Both clinical groups had similar RT deficits and ERP anomalies across several components, which correlated with psychopathology and RT priming. In OCD alone, N1 latency tended to increase to repeated stimuli, correlated with O-C symptoms, whereas it decreased in other groups. OCD-checkers had smaller target P2 amplitude than all other groups. Conclusions: Enhanced neural priming is not unique to OCD and may contribute to salient sensory-cognitive experiences in anxiety generally. These effects are related to symptom severity and occur to neutral stimuli and in the context of overall RT impairment, suggesting they may be clinically relevant and pervasive. The results indicate overlapping information-processing and neurobiological factors across disorders, with indications of OCD-specific trends and subgroup differences. Significance: This first electrophysiological investigation of OCD priming in OCD to include anxious controls and OCD subgroups allows for differentiation between overlapping and OCD-specific phenomena, to advance neurobiological models of OCD.

Keywords
panic, disorders, electrophysiology, priming, facilitation, obsessive, compulsive

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Title Page

Electrophysiology of facilitation priming in obsessive-compulsive and panic disorders.

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Highlights

- We conducted the first electrophysiological investigation of repetition priming in obsessive-compulsive disorder (OCD) to include anxious and healthy controls and the first ERP study to consider OCD symptom subgroups.
- Repetition priming was exaggerated in both OCD and panic disorder, and related to atypical ERP topography and symptom severity.
- P2 amplitude to targets was significantly smaller in a non-washing/checking subgroup of OCD than all other groups.

Abstract

Objective: Repeated experience with stimuli often primes faster, more efficient neuronal and behavioural responses. Exaggerated repetition priming effects have previously been reported in obsessive-compulsive disorder (OCD), however little is known of their underlying neurobiology or disorder-specificity, hence we investigated these factors.

Methods: We examined event-related potentials (ERPs) and behaviour while participants with OCD, panic disorder and healthy controls (20 per group) performed a Go/ NoGo task which manipulated target repetition sequences.

Results: Both clinical groups showed stronger reaction time (RT) priming than HCs, which in OCD was greater in a checking, than washing, subgroup. Both clinical groups had similar RT deficits and ERP anomalies across several components, which correlated with psychopathology and RT priming. In OCD alone, N1 latency tended to increase to repeated stimuli, correlated with O-C symptoms, whereas it decreased in other groups. OCD-checkers had smaller target P2 amplitude than all other groups.

Conclusions: Enhanced neural priming is not unique to OCD and may contribute to salient sensory-cognitive experiences in anxiety generally. These effects are related to symptom severity and occur to neutral stimuli and in the context of overall RT impairment, suggesting they may be clinically relevant and pervasive. The results indicate overlapping information-processing and neurobiological factors across disorders, with indications of OCD-specific trends and subgroup differences.

Significance: This first electrophysiological investigation of OCD priming in OCD to include anxious controls and OCD subgroups allows for differentiation between overlapping and OCD-specific phenomena, to advance neurobiological models of OCD.

Keywords: OCD, anxiety, priming, ERPs, washers, checkers, facilitation

Introduction

Efficient selective attention requires both inhibition of irrelevant information and facilitation of task-relevant information (Ghatan, Hsieh, Petersson, Stone-Elander, & Ingvar, 1998; Harnishfeger, 1995; Wright et al., 2006). Much previous research has investigated whether OCD symptoms may be caused by failures in inhibiting irrelevant thoughts from entering consciousness. While inhibitory deficits are reported in OCD studies, results are inconsistent and OCD-specific deficits have yet to be identified. In addition to inhibitory deficits, undue facilitation of attention or actions could contribute to repetitive thoughts and behaviours in psychiatric disorders such as OCD (Bannon, Gonsalvez, & Croft, 2008; Hartston & Swerdlow, 1999). It could be that due to facilitated priming processes, mental or motor acts in OCD have a greater initial activation, resulting in their atypical maintenance (Bannon, et al., 2008; Hartston & Swerdlow, 1999; Steffen Moritz & von Muhlenen, 2005). This possibility has received little attention in the research literature, and physiological studies of priming processes in OCD are lacking.

1.1 Facilitation priming

Facilitation priming is defined as improved processing (in either reaction time [RT] or accuracy of responses), resulting from previous or simultaneous encounters with a stimulus (Posner & Snyder, 1975), and allowing more efficient responding to repeated stimuli (Bunzeck, Schütze, & Düzel, 2006). Behavioural priming is usually accompanied by neural markers of priming, typically repetition-related reductions in hemodynamic activity in some cortical regions in fMRI studies (Bunzeck, et al., 2006). Priming processes do not require conscious awareness but can be modulated by top-down processes such as subjective expectancy (Vervaeck & Boer, 1980).

Repeated experience with a stimulus may lead to a sharpening of the representation of stimulus features in the cortex accompanied by a smaller, more selective, neuronal

response and a faster, more efficient, behavioural response (Grill-Spector, Henson, & Martin, 2006). Additionally, repetition may lead to faster identification and processing of repeated stimuli accompanied by shorter durations of neural firing (Grill-Spector, et al., 2006). This "repetition suppression" effect in cortical neurons constitutes a form of automatic perceptual learning allowing quick and efficient identification of previously encountered objects (Wiggs & Martin, 1998). Effects can accumulate over trials leading to higher-order effects including non-linear effects, such as plateaus or reversals in fMRI or ERPs (Grill-Spector, et al., 2006).

In ERP studies, component amplitudes often show graded changes with higher-order stimulus repetitions (Friedman & Cycowicz, 2006; Rugg, Pearl, Walker, Roberts, & Holdstock, 1994; Squires, Wickens, Squires, & Donchin, 1976). Additionally, reduced ERP component latencies are reported in association with RT facilitation effects (Lobaugh, Chevalier, Batty, & Taylor, 2005; Taylor, 2002).

1.2 Priming in OCD

Excessive RT priming has been reported in people with OCD in visuospatial priming tasks (Hartston & Swerdlow, 1999), in terms of faster RTs to probes following earlier primes in the same visuospatial locations. These effects may indicate an exaggerated focus on already-experienced targets, possibly contributing to the automatic and repetitive nature of obsessions, whereby disturbing mental images become primed in OCD facilitating their own reoccurrence (Hartston & Swerdlow, 1999). Similarly, perseveration errors in OCD following previously correct responses in a delayed alternation task have been attributed to problems disengaging from previously occupied valid locations (Steffen Moritz et al., 2009). Thought suppression studies indicate enhanced priming of neutral words after attempts to suppress them in individuals with OCD (Tolin, Abramowitz, Przeworski, & Foa, 2002). There has been one fMRI study of repetition priming in 12 young people with OCD versus healthy

controls, which manipulated prime-target relationships. Participants with OCD had slower behavioural responses across conditions than healthy controls, interpreted as possible "obsessional slowness", and abnormal activation in parietal, temporal and precuneus regions in repetition trials (Viard et al., 2005). Because of the lack of a clinical comparison group the study was limited in determining the specificity of effects to OCD.

Some studies (Bannon, Gonsalvez, Croft, & Boyce, 2002; Herrmann, Jacob, Unterecker, & Fallgatter, 2003) have reported faster RTs to Go stimuli in Go/NoGo tasks in OCD compared to normal or anxious controls. An intriguing possibility is that RTs become faster in OCD with stimulus repetition due to excessive priming effects. To test this possibility, it is necessary to analyse whether RTs to Go stimuli become faster with stimulus repetitions, however no previous studies have examined this issue.

There are some indications that mechanisms which are related to anxiety may also contribute to repetition priming. In healthy volunteers, behavioural and fMRI repetition effects are strongly attenuated with lorazepam, suggesting that GABAergic and cholinergic systems influence the neuronal plasticity necessary for repetition priming (Thiel, Henson, Morris, Friston, & Dolan, 2001). Conversely, facilitated processing of internal and external stimuli in anxiety has been linked to excessive excitability of cortical cholinergic inputs from the basal forebrain (Berntson, Sarter, & Cacioppo, 1998). Benzodiazepine receptor agonists impede cognitive and attentional processing of a broad range of stimuli, and their anxiolytic effects may be due to a reduction in exaggerated cortical processing of anxiogenic stimuli (Berntson, et al., 1998). Given the nature of these mechanisms, it is possible that exaggerated priming may occur in anxiety disorders generally rather than being specific to OCD, however comparisons across disorders are lacking in the literature.

1.3 OCD subgroups

The clinical heterogeneity of OCD symptoms has led to research into the

neuropsychological characteristics between OCD subgroups. In several studies of attention and behaviour, those who primarily exhibit cleaning compulsions (washers) have been found to differ from those whose primary compulsions are not washing but checking or performing other rituals (termed non-washers or checkers; Ceschi, Van der Linden, Dunker, Perroud, & Brédart, 2003; Foa, Ilai, McCarthy, Shoyer, & Murdock, 1993; Matsunaga et al., 2002; S Moritz & von Mühlenen, 2008; Nedeljkovic et al., 2009; Omori et al., 2007; Phillips et al., 2000; Summerfeldt, Richter, Antony, & Swinson, 1999; Van der Linden, Ceschi, Zermatten, Dunker, & Perroud, 2005; K. Wahl, P.M. Salkovskis, & I. Cotter, 2008). The heterogeneity of OCD can reduce the power of, and obscure, research findings unless sub-groups are considered (Hasler et al., 2007; Heyman, Mataix-Cols, & Fineberg, 2006). Although individuals with OCD may exhibit both behaviours, usually one type of ritual predominates, permitting individuals to be classified as a washer or checker (Fontenelle, Mendlowicz, & Versiani, 2005; Steketee, Grayson, & Foa, 1985). Presently, there is no one established method to identify OCD symptom subtypes (Julien, O'Connor, Aardema, & Todorov, 2006) and previous studies use clinical interviews and a variety of OCD questionnaire measures with washing/checking subscales. The question of differences between symptoms subtypes and facilitation priming has rarely been investigated, however one study reported that visuospatial priming facilitation was most pronounced in OCD participants who reported a history of violent images, tics, "just right" obsessions, or checking compulsions (Hartston & Swerdlow, 1999). There are no previous ERP studies considering differences between OCD symptom subgroups.

In summary, several studies suggest the possibility of atypical priming in OCD, however direct examinations of brain activity are lacking, limiting conclusions about the physiological bases which may be involved. Additionally, it is necessary to compare brain activity accompanying priming in OCD with that of a clinical comparison group to determine the

specificity of any effects to OCD.

We previously described an experimental task designed to separately examine both inhibitory and facilitatory aspects of selective attention (Susan Jennifer Thomas, Gonsalvez, & Johnstone, 2009). This is a modified Go/NoGo task in which facilitation and inhibitory load were manipulated by varying the number of Go stimuli preceding Go and NoGo stimuli. In healthy participants, responses to Go stimulus repetitions were facilitated, indexed by shorter RTs, P1 and N1 latencies. Conversely, increasing the numbers of preceding Go stimuli resulted in greater inhibitory difficulty to NoGo stimuli, indexed by incremental increases in N1, P2 and N2 latencies.

In the current study we used the previously established experimental approach (Susan Jennifer Thomas, et al., 2009) to examine brain activity correlated with repetition priming in OCD. To examine the specificity of effects to OCD, we included an anxious comparison group with panic disorder, as well as healthy controls (HCs). We aimed to establish whether there are facilitation priming anomalies in OCD and if so whether they are unique to OCD or shared with another disorder (panic disorder). Here we report the facilitation priming results only. The inhibition results are reported previously (Susan J Thomas, Gonsalvez, & Johnstone, 2014).

2. Method

2.1 Participants

Sixty individuals participated, who also participated in our previous study (Susan J Thomas, et al., 2014): 20 with OCD, 20 with panic disorder with or without agoraphobia (PD), and 20 HCs. Clinical participants were recruited through local clinics. Clinical participants were screened beforehand by telephone to exclude those with likely current depression. Diagnoses were confirmed using the Composite International Diagnostic Interview for DSM-IV, World Health Organisation (1997). HCs were free from past or

present psychiatric disorders. Exclusion criteria across groups were head injuries, neurological disorders, substance abuse and psychoses. The University of Wollongong Health and Medical Human Research Ethics Committee approved the research protocol and participants gave written informed consent.

Twelve participants with OCD and ten with panic disorder were medicated around the time of testing. In the OCD group, 8 participants were taking selective serotonin re-uptake inhibitors (SSRIs), 2 serotonin- norepinephrine reuptake inhibitors (SNRIs), 1 a reversible inhibitor of monoamine-oxidase-A (RIMA), and 1 was taking occasional benzodiazepine. In the PD group, 6 participants were taking SSRIs, 1 a tricyclic anti-depressant, and 3 were taking occasional benzodiazepines (including two participants prescribed combined SSRI and benzodiazepines). No patients were medicated with benzodiazepines at the time of testing.

OCD patients were also categorised into subtypes on the basis of their current primary obsessions and compulsions in order to consider whether performance diverged between subgroups. Following previous studies (Lavy, Van Oppen, & Van Den Hout, 1994; Karina Wahl, Paul M Salkovskis, & Imogen Cotter, 2008), OCD participants were classified as washers if their sole or primary compulsions were focused on cleaning, and non-washers/ checkers if their primary compulsions were not washing but checking or other rituals. Ten OCD participants indicated predominantly washing problems and had higher scores on the Washing than Checking subscales of the Padua Inventory-Washington State University Revision (PI-WSUR; Burns, Keortge, Formea, & Sternberger, 1996) which are reliable and valid indicators of these subtypes (Heyman, et al., 2006; Lavy, et al., 1994). The remaining ten OCD participants indicated predominantly checking problems and had higher scores on the Checking than Washing subscales of the PI-WSUR.

2.2 Materials

Symptom types and severity were assessed using the PI-WSUR (Burns, et al., 1996),

the Yale-Brown Obsessive Compulsive Scale (Goodman et al., 1989), the Brief Symptom Inventory (BSI; Derogatis & Melisaratos, 1983) and Obsessional Beliefs Questionnaire (OBQ-44; Obsessive compulsive cognitions working group 2001, 2005; 1997).

2.3 Stimuli

Stimuli were as described in our previous study (Susan J Thomas, et al., 2014), presented individually on a computer screen in white on a black background, in sequences or trains of 4-8 (See Fig. 1). Stimulus trains commenced with a baseline stimulus (!), followed by between 1-4 Go stimuli (✓; coded as G-GGGG). At the end of trains, some further stimuli followed which were included for examination of inhibition and task switching performance[1]. These included a NoGo stimulus (X), which was followed on 50% of trials by a repetition of the X-stimulus (because participants were required to respond to X-repetitions, this stimulus is termed X-Go) and on 50% of trials by a square (dedicated NoGo stimulus). Thus a NoGo (N) stimulus occurred in each train, but because N was preceded by one or more Go-stimuli, the overall ratio of Go: NoGo stimuli was 14:4 or 69:31%. Train types were equiprobable and presented randomly. Stimulus duration was 200 ms. ISI varied randomly between 1-3 s (mean 2 s) and inter train interval varied randomly between 4-6 s. Overall 635 stimuli were presented.

2.4 Procedure

After completing interviews and questionnaires, electrode caps were fitted and participants were comfortably seated in a dimly lit sound-attenuated room, 1m from the

[1] We previously reported an analysis of the Go versus NoGo stimuli to investigate inhibitory processing across groups. Here we interrogate the Go stimuli only, as a function of their serial position, to investigate the different research question of the effects of repetition priming on ERPs and RTs to Go stimuli across groups and subgroups.

computer screen, with a button-press device fixed to a chair arm next to their dominant hand.

2.5 Electrophysiological recording

The EEG was recorded from 19 scalp electrodes and referenced online to linked ears according to the international 10 – 20 system (JASPER, 1958) using tin electrodes in an electrode cap. The participant was grounded by a cap electrode located midway between Fpz and Fz. Vertical EOG was recorded from electrodes placed 1 cm above and below the left eye, and electrodes placed beyond the outer canthus of each eye recorded horizontal EOG. Electrode impedances were below 5kΩ.

2.6 Data analysis

One-way analyses of variance (ANOVAs) were used to compare groups on age and psychometric variables. Fisher's exact test was used to compare group categorical variables. Significant differences between groups were followed by simple effects comparisons.

Mean RTs for correct responses by stimulus type were calculated for each participant in each task. Extreme scores (± 2 SDs from the participant's condition mean) were excluded. Mean RTs and errors were analyzed using a 3 Group (HC, panic disorder, OCD) x 4 Repetition (G, GG, GGG, GGGG) ANOVA. Two planned contrasts were employed: A linear contrast determining whether Go stimulus repetitions were related linearly to RT, and a quadratic contrast comparing mid-train effects with early and late effects.

The ERP epoch was defined as 100 ms pre- to 800 ms post-stimulus. ERP data were amplified with EEG and EOG gains of 20,000 and 5,000 respectively, digitized at a sampling rate of 512 Hz with a bandpass down 3 dB at 0.01 and 35 Hz, and filtered offline with a low pass zero phase shift filter at 30 Hz, 48dB/octave. Data were accepted after artifact rejection (±100μV) and eye-movement correction (Semlitsch, Anderer, Schuster, & Presslich, 1986).

Five components were quantified with amplitudes determined relative to the 100 ms pre-

stimulus baseline. Peaks were detected in specified channels where they generally showed maximal amplitude in the grand mean waveforms: O1 for P1 (50–120ms); O2 for N1 (90–160 ms); Pz for P2 (150 - 210 ms); Fz for N2 (180 - 400 ms), and Pz for P3 (290 - 600 ms). Eleven sites were the focus of data analysis (F3, Fz, F4, C3, Cz, C4, P3, Pz, P4, O1, O2). ERP latencies were recorded as the time during the search window of maximal amplitude at the site where the component was quantified, and relative amplitude measures for all 11 electrodes were taken at the same post-stimulus latency (Picton et al., 2000).

Within the lateral plane, two planned contrasts were computed: left versus right hemispheres, and the midline region versus the mean of the left and right hemispheres. The contrasts for the Sagittal factor were frontal versus parietal electrodes and central versus the mean of the frontal and parietal electrodes. As the contrasts were planned and there were no more of them than the degrees of freedom for an effect, no Bonferroni-type adjustment was necessary (Tabachnick, Fidell, & Osterlind, 2001). Greenhouse–Geisser corrections were applied where appropriate. ERP data were normalized using the vector scaling procedure (McCarthy & Wood, 1985), and interactions involving topography are reported only if they remained significant after normalisation.

To assess whether any Group effects or interactions may have been related to medication status, for each clinical group separately, analyses were repeated as above with a between group factor of Medication, with 2 levels (no medication, current medication). Any Group effects or interactions are only reported if no involved variables interacted with Medication status. Additionally, where groups differed significantly in the main analyses, we examined the subgroup means for washers and non-washers and where these appeared notably to diverge, simple effects analyses between subgroups were conducted.

3. Results

3.1 Group characteristics and psychometric variables

Table 1 shows group and subgroup characteristics and scores for psychometric questionnaires. Participant characteristics were as reported in our previous study (Susan J Thomas, et al., 2014), however here we include a further breakdown to include OCD subgroups. There were no significant differences between the three groups for age, gender or handedness. The OCD group showed significantly higher scores than the HC group on all measures of psychopathology. There were no significant differences between the OCD and PD groups on measures of psychological symptoms (including depression) with the exception that, as expected, the OCD group showed significantly higher scores on the PI-WSUR. The PD group showed significantly higher scores than the HC group on all measures of psychopathology with the exception of measures of obsessive-compulsive symptoms (the BSI O-C subscale, and PI-WSUR). The OCD washers did not differ significantly from the non-washers/ checkers on any demographic or psychometric variables ($p > .05$ for all comparisons) except that the washers scored significantly higher than the non-washers/checkers (23 vs. 8 respectively) on the Contamination and Washing subscale of the PI-WSUR, F (1,18) = 10.79, p = 004.

3.2 Behavioural results

Table 2 shows mean behavioural data across groups. There were no interactions between Medication and performance. There was a main effect of Group, F (2, 57) = 4.27, p = .019, with simple effects confirming that both clinical groups had longer RTs than the HC group (OCD vs. HC: F (1, 38) = 5.48, p = .025; PD vs. HC: F (1, 38) = 8.72, p = .005). Accuracy to baseline stimuli was high and did not differ by Group or subgroup. With Go stimulus repetitions, RT decreased (linear contrast), F (1,57) = 24.1, $p < .001$, with this pattern being qualified in that RT reductions were larger for initial repetitions than they were for subsequent repetitions (quadratic effect), F (1,57) = 64.43, $p < .001$. A significant Group by Stimulus interaction and simple effects indicated that the PD group showed a greater RT reduction

from G to GGGG than the HCs (linear contrast), F (1, 38) = 9.68, p = .004, (Fig. 2). A similar trend occurred in the OCD group, F (1, 38) = 3.56, p = .067; Table 2). Examination by OCD subgroups showed that the OCD non-washers/ checkers (but not washers) showed a significantly greater reduction in RT to Go stimulus repetitions compared to the HCs, (linear contrast), F (1,18) = 5.53, p = .026. With repetitions of Go stimuli, there was a decrease in omission errors, (linear contrast), F (1, 57) = 7.2, p = .010, across groups. The accuracy of responses to Go stimuli did not differ between groups or subgroups.

3.3 ERPs to Baseline stimuli

ERPs to baseline stimuli were analysed using a 3 Group (HC, PD, OCD) x 3 Sagittal plane (frontal, central, parietal) x 3 Lateral plane (left, midline, right) mixed design ANOVA. Mean amplitudes and latencies of ERP components by Group are shown in Table 3. ERPs to baseline stimuli are shown in Fig. 3. Between-Group differences in waveforms are visually apparent, particularly a reduced parietal relative to frontal P3 amplitude in the clinical groups versus the healthy control group.

P1: A main effect of Group, F (2, 57) = 5.2, p = .008, and simple effects analyses indicated that both anxious groups had smaller P1 amplitude to baseline stimuli than the HC group, (OCD vs. HC*:* F (1, 38) = 5.57, p = .024; PD vs. HC: F (1, 38) = 9.14, p = .004; Fig. 4).

N1: Amplitude differed by Group, F (2, 57) = 3.32, p = .043, with simple effects indicating that this was driven by larger N1 amplitudes to Baseline stimuli in the PD and OCD groups than in the HCs (OCD vs. HC*:* F (1, 38) = 4.51, p = .04; PD vs. HC: F (1, 38) = 5.09, p = .03).

N2: Amplitude showed a Sagittal by Group interaction, F (2, 57) = 5.69, p = .006. Both the OCD, F (1, 38) = 5.76, p = .021, and PD, F (1, 38) = 9.79, p = .003, groups showed attenuated Frontal > Parietal effects for N2 amplitude relative to HCs.

P3: Amplitude showed an interaction between Sagittal plane and Group, F (2, 57) = 6.48, p = .003. Both the OCD, F (1, 38) = 9.97, p = .003, and PD, F (1, 38) = 10.28, p = .003, groups showed a smaller Parietal > Frontal topography of P3 compared to the HCs (Fig. 4).

3.4 ERPs to Go stimuli as a function of repetition priming

Facilitation was examined using a 3 Group (HC, panic disorder, OCD) x 4 Stimulus type (G, GG, GGG, GGGG) x 3 Sagittal plane (frontal, central, parietal) x 3 Lateral plane (left, midline, right) ANOVA. Only interactions involving Stimuli or Group are reported. Because the focus of this study is on between-group differences, only main effects and interactions involving Group are plotted. Effects and interactions as a function of repetition in healthy participants have been presented fully elsewhere (Susan Jennifer Thomas, et al., 2009). P1 peaks were smaller to Go than to baseline stimuli and while they were generally discernible in the individual participants' average waveforms, they are difficult to discern in the grand mean waveforms to Go stimuli. Additionally we did not find any group or experimental effects for P1 to Go stimuli, hence the P1 to Go stimuli are not further considered. For N1 amplitude, an additional ANOVA was conducted at occipital electrodes (O1, O2), excluding the Sagittal factor. Grand average ERPs to Go stimulus repetitions are shown in Fig. 5.

N1: Across groups, a significant linear contrast indicated that N1 amplitude reduced with repetitions of Go stimuli within trains, F (1, 57) = 6.5, p = .024. N1 latency differed by Group, F (2, 57) = 5.63, p = .006, with OCD, F (1, 38) = 11.15, p = .002, and panic disorder groups having longer N1 latency to Go stimuli than HCs, F (1, 38) = 7.6, p = .009. There was a marginal Group by Stimulus position interaction, F (2,57) = 2.61, p = .08, with HCs showing decreases in N1 latency with Go repetitions, and the OCD group showing increases (linear contrast; OCD versus HC, F (1,38) = 6.19, p = .01). The panic disorder group also showed a pattern of decreasing N1 latency to Go repetitions but did not differ significantly to other groups, p > .05 (Fig. 6).

P2 amplitude differed by Group, F (2, 57) = 3.2, p = .046, driven by smaller P2 amplitude in the OCD than HC group, F (1, 38) = 5.96, p = .012. A Group x Sagittal interaction was significant, F (2, 57) = 3.48, p = .033, driven by smaller parietal (vs. frontal) topography in the OCD versus HC group, F (1, 38) = 5.96, p = .017. Examination of subgroup means indicated that the between group effect appeared to be driven by the non-washing/ checking subgroup, and simple effects analyses by subgroups indicated that the non-washers/ checkers had smaller P2 amplitudes than the PD group, F (1, 18) = 4.09, p = .05, whereas the washers had equivalent P2 amplitudes to the PD group (Fig. 7).

For N2 amplitude, a Sagittal by Group interaction, F (2, 57) = 5.09, p = .009, and simple effects indicated that the N2 Frontal > Parietal effect was reduced in both clinical groups compared to HCs (OCD vs. HC: F (1, 38) = 4.27, p = .030; panic disorder vs. HC: F (1, 38) = 4.08, p = .007; Fig. 6). A Group by Laterality (quadratic) interaction, F (1, 38) = 3.5, p = .022, indicated a stronger midline > hemispheres effect in panic disorder than OCD, F (1, 38) = 6.3, p = .011 (Fig. 6). With Go repetitions, N2 amplitude showed overall linear reductions, qualified by a quadratic pattern involving initial decreases followed by increases (linear: F (1, 57) = 4.29, p = .043; quadratic: F (1, 57) = 4.8, p = .036). With Go repetitions, N2 latencies reduced linearly, F (1, 57) = 5.24, p = .026.

P3: With Go repetitions, the Parietal: Frontal topography decreased, F (1, 57) = 10.64, p = .004. P3 amplitude decreased in the right relative to left hemisphere, F (1, 57) = 4.74, p = .034, with Go repetitions, with a quadratic contrast, F (1, 57) = 16.22, p = .001, indicating that the initial decrease was greater than those to further repetitions. A Group main effect, F (2, 57) = 4.94, p = .01, showed that the clinical groups had longer P3 latencies to Go stimuli than the HCs (OCD vs. HC: F (1, 38) = 5.8, p = .021; panic disorder vs. HC: F (1, 38) = 9.2, p = .004). A significant linear contrast indicated that P3 latencies reduced with repetitions of Go stimuli within trains, F (1, 57) = 14.82, p < .001.

This was qualified by a quadratic effect where latencies increased towards the end of longer stimulus trains, F (1, 57) = 16.22, p < .001.

3.5 Relationships between variables

To determine the relationship between experimental effects, OCD symptoms and other psychopathology, we conducted Pearson correlations between the significant ERP/RT effects listed above and symptom severity as measured by Y-BOCS and PI-WSUR totals, BSI total and selected BSI subscale scores (Obsessive-Compulsive (O-C) scale, Depression and Anxiety). For effects which differed by OCD subgroup we also correlated PI-WSUR Contamination/ washing and Checking subscale scores. Critical alpha for all correlations was set to .01.

RT facilitation accompanying stimulus repetition correlated with Y-BOCS Total, r (20) =.59, p = .01. For baseline stimuli, reduced Frontal > Parietal topography of N2 amplitude correlated broadly with symptom severity (PI-WSUR, BSI O-C, Depression, Anxiety, BSI Total), r (60) between -.33 and -.46. Smaller Parietal > Frontal topography of P3 amplitude to baseline stimuli correlated with RT facilitation to repeated stimuli, r (60) = .41, and with symptom severity (BSI O-C, Depression and Anxiety), r (60) between -.36 and -.51.

For target stimuli, increasing N1 latency as a function of Go stimulus repetition correlated with BSI O-C scores, r (60) =.38. Mean P2 amplitude at parietal electrodes (P3, Pz, P4) correlated negatively with Padua PI-WSUR Checking, BSI Anxiety and BSI Total, r (60) between -.36 and -.40. For N2, reduced Frontal > Parietal topography correlated BSI-O-C scale and BSI Anxiety, r (58) = between -0.34 and -.43. P3 latency correlated with BSI Anxiety, r (60) =.35. Reduced Parietal > Frontal P3 amplitude to Go stimuli correlated with BSI-O-C scale, r (60) =.39 and BSI Anxiety, r (60) =.42.

4. Discussion

The current study investigated whether OCD participants show exaggerated behavioural or neural facilitation to stimulus repetitions. To our knowledge it was the first examination of neural correlates of repetition priming in OCD versus healthy and clinical controls, and the first ERP study to consider OCD symptom subgroups.

4.1 Is there exaggerated priming in OCD?

Our experimental task allowed the comparison of perceptually identical targets which varied only on preceding stimulus sequences. Across groups, there were behavioural indications of priming including reductions in RTs, and increased accuracy, as a function of stimulus repetition. Both PD and OCD groups showed indications of enhanced repetition priming, with RT to go-stimulus repetitions decreasing at a greater rate than for HCs. When considered at the subgroup level, OCD non-washers/ checkers but not washers showed a significantly greater linear reduction in RT to Go stimulus repetitions compared to the HCs. Both negative priming (Simon J. Enright, Beech, & Claridge, 1995) and positive priming (Hartston & Swerdlow, 1999) anomalies and neuropsychological impairments (Nedeljkovic, et al., 2009) are reported to be more robust in checkers and those with violent obsessions, thought to indicate greater information-processing impairment in this subgroup.

RT reductions to stimulus repetitions have been interpreted as sensory-motor facilitation, possibly due to mental representations left by previous stimulus-response cycles (Vervaeck & Boer, 1980). Exaggerated priming effects have been found previously in panic disorder for threat-related material (Amir, McNally, Riemann, & Clements, 1996; McNally, 1995), however priming abnormalities involving neutral stimuli have largely been overlooked in panic disorder, and we are not aware of any previous studies.

Unlike previous RT studies using a different priming task (Bannon, et al., 2008; Bannon, et al., 2002), the current RT results do not support an OCD-specific exaggerated

facilitation effect as the panic disorder group showed similar effects. Taken in conjunction with previous findings that anxiolytic drugs strongly attenuate fMRI repetition effects (Berntson, et al., 1998), the current results may be consistent with a broader interpretation that anxiety is associated with enhanced priming, possibly due to exaggerated cortical processing of stimuli (Berntson, et al., 1998). Skin conductance research indicates that individuals with panic disorder show "enhanced conditionability" in classical conditioning paradigms where neutral stimuli, paired with aversive stimuli, become conditioned to elicit a fear response (Michael, Blechert, Vriends, Margraf, & Wilhelm, 2007). Previous behavioural research has additionally demonstrated that enhanced perceptual priming of neutral stimuli can contribute to anxiety by triggering threatening stimuli which are perceptually similar to, or which have become associated with, traumatic stimuli (Ehlers, Michael, Chen, Payne, & Shan, 2006). In the current study, correlations between ERPs, RT priming and symptom severity suggest that these effects may be relevant to the aetiology and maintenance both conditions. Exaggerated perceptual priming may be a mechanism contributing to fear conditioning and reduced extinction in anxiety disorders, through sharpened mental representations of stimuli facilitating fear conditioning (involving threat-neutral associations). The inclusion of ERPs in the current study provides additional information about repetition-related cortical activity between groups and subgroups.

4.3 Repetition-related cerebral processing

Across groups, behavioural repetition priming was accompanied by linear reductions in N1 amplitude, N2 latency and in parietal versus frontal P3 amplitude. The results are consistent with previous studies demonstrating N1 amplitude reductions to stimulus repetitions and increases to deviant stimuli (Horváth, Winkler, & Bendixen, 2008). The N1 is sensitive to stimulus change and may index filtering of sensory information, possibly to

reduce load on limited-capacity processing resources (Horváth, et al., 2008). Faster N2 latencies suggest that repeated stimuli were processed more quickly, consistent with previous studies reporting reduced ERP latencies in association with RT facilitation effects (Lobaugh, et al., 2005; Taylor, 2002). Reduced amplitude of parietal P3 has also been previously noted to primed, non-semantic, visual stimuli (Werheid, Alpay, Jentzsch, & Sommer, 2005), possibly indicating reduced stimulus analysis with repetition (Rugg, Soardi, & Doyle, 1995).

As in our previous examination of this task, we found higher-order effects with some variables (RT, N2 amplitude, P3 latency) showing decreases with initial repetitions which reversed towards the end of longer stimulus trains, likely due to expectancy or serial position effects (Susan Jennifer Thomas, et al., 2009). Participants may have anticipated an impending change of stimulus by the third or fourth Go repetition, or attentional allocation resources may have altered later in trains due to serial position effects (Susan Jennifer Thomas, et al., 2009).

There was an OCD-specific tendency whereby N1 latency increased linearly to stimulus repetitions whereas it decreased in all other groups. N1 latency reflects the speed of stimulus discrimination processes (J. H. K. Vogel et al., 2005) and increases with greater effort at processing (Callaway & Halliday, 1982). This could potentially indicate a deficit in selective attention, involving slower or less efficient processing as a function of repetition. This could be related to an exaggerated tendency to focus on already-experienced targets previously noted in OCD (Hartston & Swerdlow, 1999; Steffen Moritz, et al., 2009; Tolin, Hamlin, & Foa, 2002), localised during stimulus discrimination stages, which may perpetuate repetitive symptoms. Impairment in repetition priming (S. J. Enright, 1993) and in implicit sequence learning, accompanied by enhanced recognition of embedded stimulus patterns (Marker, Calamari, Woodard, & Riemann, 2006), have previously been reported in OCD and interpreted as gating deficits, whereby stimuli which

are normally processed outside of conscious awareness are processed consciously and inefficiently, in turn increasing thought salience. Interference in automatic processing of repeated stimuli indicated in the current study could conceivably be related to OCD symptomatology such as uncertainty as to whether an action has previously been performed. This result is interpreted cautiously, because the differences between groups were only marginal in the three-group comparison. Sub-group sizes were small, possibly limiting the power of the subgroup analyses, and further research is warranted.

While N2 components were negative-going deflections, defined as the largest negative-going peak within the search window, the absolute amplitudes of grand mean N2 amplitudes in the current study were small and in some cases positive. This appears to be the case in previous Go/NoGo studies, particularly for Go stimuli, which are the main focus of the current investigation, (e.g. Bokura, Yamaguchi, & Kobayashi, 2001; Bruin & Wijers, 2002; Falkenstein, Hoormann, & Hohnsbein, 1999; Freitas, Azizian, Leung, & Squires, 2007).

4.2 Other between-group differences

Both clinical groups showed slower RTs overall compared to HCs, which was not correlated with depressive symptoms and did not differ by medication status. Slowed RTs are commonly reported in OCD studies and where these do not include clinical control groups, this phenomenon may be given an OCD-specific interpretation, such as “obsessional slowness” (e.g. Viard, et al., 2005). Because both clinical groups showed slower RTs overall, we interpret this as a general impairment related to clinical status.

Greater repetition priming occurred in the clinical groups despite slower overall RTs. While this may seem counterintuitive, previous research indicates that priming effects do not necessarily equate to overall RT efficiency, and a greater slope of priming effects may co-occur with slower overall RTs (Kliegl, Masson, & Richter, 2010). Clinical groups often show impaired RT performance in a variety of tasks (Gualtieri & Morgan, 2008; Kuelz, Hohagen,

& Voderholzer, 2004; Olley, Malhi, & Sachdev, 2007). Priming tasks typically involve both strategic and automatic processes (Kliegl, et al., 2010; Leonard & Egeth, 2008), and it could be, for example, that the clinical groups in the current study were impaired in some aspects of strategic performance during the task resulting in slower overall RTs, while other processes such as sensory sharpening were enhanced, resulting in simultaneously greater RT benefits to repeated stimuli.

ERPs indicated anomalies in cerebral brain activity in both clinical groups. Both clinical groups had smaller P1 and larger N1 amplitudes to baseline stimuli compared to healthy controls. The P1 component indexes the allocation of processing capacity to early visual attention and the suppression of irrelevant information (Luck et al., 1994). P1 amplitude increases with greater attention to stimuli during relatively early, sensory stages (Carretié et al., 2009; Hopfinger & Mangun, 2001). The N1 indexes stimulus discrimination processes (E. K. Vogel & Luck, 2000) and conscious detection of change in the environment (Hyde, 1997). Potentiated N1 amplitude may indicate greater activation of stimulus discrimination processes (E. K. Vogel & Luck, 2000). The current results may indicate impaired early (P1) visual attention or suppression of irrelevant information, followed by greater attentional responses during stimulus discrimination (N1) stages while attending to task-irrelevant baseline stimuli. Higher N1 amplitude to behaviourally irrelevant stimuli has been previously reported in PD and interpreted as a reduced ability to filter and discard stimuli of low significance (Wise, McFarlane, Clark, & Battersby, 2009). The P1-N1 results to baseline stimuli may therefore reflect increased distractibility in both disorders.

For target stimuli, both clinical groups showed longer N1 latencies compared to healthy controls. Longer N1 latency to Go stimuli has previously been reported for OCD participants versus healthy controls (Di Russo, Zaccara, Ragazzoni, & Pallanti, 2000; Morault, Bourgeois, Laville, Bensch, & Paty, 1997) however the current study demonstrates that this is not an OCD-

specific anomaly. The current results suggest slower or more effortful processing during stimulus discrimination in both clinical groups.

P2 amplitude to target stimuli was smaller in participants with OCD than HCs, particularly in parietal regions. Parietal P2 amplitude to Go stimuli also correlated negatively with obsessive-compulsive, checking and anxiety symptoms. P2 indexes central processes responsible for discriminating and classifying stimuli (Lindholm & Koriath, 1985) and inhibiting sensory input from further processing (Hegerl & Juckel, 1993) and is linked to vigilance, arousal (Dowman, 2004) and serotonin activity (Hegerl, Gallinat, & Juckel, 2001; Hegerl & Juckel, 1993; Juckel, Molnár, Hegerl, Csépe, & Karmos, 1997; Senkowski, Linden, Zubrägel, Bär, & Gallinat, 2003). Smaller P2 amplitudes have previously been reported in OCD (Oades, Dittmann-Balcar, Schepker, Eggers, & Zerbin, 1996) and in panic disorder (Wang et al., 2003). We noted a similarly small and atypically distributed P2 results to NoGo stimuli in OCD in a previous study (Susan J Thomas, et al., 2014), suggesting that this is not specific to either inhibition or facilitation but relates to more general anomalies. In conjunction with previous studies (Susan J Thomas, et al., 2014; Wang, et al., 2003), the P2 amplitude results may index serotonergic-mediated anomalies in information-processing and arousal occurring across these anxiety-related disorders. P2 amplitude was significantly smaller to Go stimuli in the non-washing/ checking subgroup of OCD participants than in all other participants. This may represent a biological correlate of more severe information-processing impairments reported in neuropsychological studies in such participants (Simon J. Enright, Claridge, Beech, & Kemp-Wheeler, 1994; Hartston & Swerdlow, 1999; Nedeljkovic, et al., 2009). We are not aware of any previous ERP studies to compare OCD subtypes, however previous neuroimaging studies also report distinct patterns of brain activation in participants with washing/ checking/ hoarding profiles (van den Heuvel et al., 2009).

Additionally, both clinical groups showed fundamental differences in topography of N2-

P3 components to baseline stimuli relative to controls, with a greater negativity in parietal regions. N2-P3 components index neural resources allocated to cognitive functions including neural inhibition mechanisms, selective attention and context updating (Falkenstein, et al., 1999; Polich & Herbst, 2000). Parietal lobe activation is strongly related to sustained attention, vigilance and effortful attention (Melloni et al., 2012; Tamm, Menon, & Reiss, 2006). Numbers of reports of parietal lobe dysfunction and structural abnormalities in OCD, which correlate with symptom severity, are increasing (Carmona et al., 2007; Ciesielski, Hämäläinen, Lesnik, Geller, & Ahlfors, 2005; Kang et al., 2003; Kwon et al., 2003; Melloni, et al., 2012; Okasha et al., 2000; Szeszko et al., 2005). Additionally, a recent meta-analysis of ERPs in panic disorder reported significantly reduced parietal amplitude of the P3 component across studies, thought to index reduced neural resources for context updating, selective attention and neural inhibition mechanisms (Howe, Pinto, & De Luca, 2014). In the current study, topographical anomalies correlated both with OCD and anxiety symptom severity and with RT facilitation priming. The relationship with symptom severity and repetition priming suggests that ERP topographical differences may be physiological indicators of clinically relevant information-processing deficits, either in the primary allocation of cognitive resources, or compensatory strategies such as effortful cognition in response to impairments (Ciesielski, et al., 2005).

The pattern of ERP results in the current study may be interpreted more globally in terms of a negativity that spans N1-P3 in posterior locations in the clinical groups which is absent in the controls. Several previous studies of attention in OCD have found larger processing negativity in individuals with OCD (Endrass, Klawohn, Schuster, & Kathmann, 2008; Klawohn, Riesel, Grützmann, Kathmann, & Endrass, 2014; Miyata et al., 1998; J. Towey et al., 1990; J. P. Towey et al., 1994) and also in non-OCD anxiety disorders (Miyata, et al., 1998; Weinberg, Olvet, & Hajcak, 2010) versus healthy controls. This is often, but not

always, noted in the context of error detection or conflict, which has been linked to anterior cingulate cortex activity (van Veen & Carter, 2002). This may be consistent with "processing negativity" which occurs during selective attention in early (100-300 ms) and late (300-500 ms) phases (Näätänen, 1982) and in the current context may denote cortical hyperarousal or overfocused attention (J. Towey, et al., 1990) in both OCD and panic disorder.

Both clinical groups also showed longer P3 latencies to Go stimuli compared to healthy controls, suggesting that less efficient attention or memory processes (see Polich & Herbst, 2000) may have contributed to their slowed response generation times. Longer P3 latencies have previously reported in panic disorder (Clark, McFarlane, Weber, & Battersby, 1996; Turan et al., 2002) and in medication-free patients with OCD (Sanz, Molina, Martin-Loeches, Calcedo, & Rubia, 2001), although shorter P3 latencies are often reported in OCD (e.g. Mavrogiorgou et al., 2002). As P3 latency did not interact with medication status in the current analyses, it is concluded that longer P3 latencies in both clinical groups are likely due to general cognitive impairments associated with clinical status.

4.5 Limitations

Several participants were on medication. The effects of medication on ERPs are unclear, with some previous studies finding no ERP or behavioural effects (Malloy, Rasmussen, Braden, & Haier, 1989; Ruchsow et al., 2007). Another study found that P300 amplitude increased in OCD from low towards normal levels with medication. (Sanz, et al., 2001). We addressed potential confounds of comparing a medicated clinical group with drug-naïve healthy controls by including two clinical groups, taking similar levels and types of medications and differing significantly only on measures of OCD. We also reanalysed data with Medication as a between-subjects factor, and in the few instances where any variable interacted with Medication, we excluded results from reporting. This reduces the likelihood, but does not preclude the possibility, that medication effects

influenced the current results.

Subgroup sizes were small, reducing the power to detect differences, and some of the effects noted differed only marginally in the overall analysis. For this reason the subgroup results are interpreted tentatively. This is to our knowledge the first study to consider ERPs within symptom subtypes of OCD. Difficulties recruiting sufficient numbers of OCD participants to consider subgroup analyses have previously been noted in the literature (Hasler, et al., 2007; Heyman, et al., 2006). Further investigation is therefore needed into ERP differences in OCD subtypes.

We examined facilitation processes in relation to neutral stimuli only. Given the clear effect of emotional content on inhibitory tasks in these disorders (Susan J Thomas, Gonsalvez, & Johnstone, 2013), it would be of interest to investigate whether repetition priming is further impaired with regard to threat-related material.

4.6 Integration and conclusions

The current results lead to the suggestion anxious individuals may show exaggerated priming effects, associated with symptom severity and differences in cortical activity, regardless of the emotional content of stimuli. The occurrence of enhanced priming effects related to symptom severity, occurring to neutral stimuli and in the context of overall RT impairment suggests they may be pervasive and relevant to the development and maintenance of symptoms in anxiety conditions. Both these clinical groups additionally showed very similar general RT impairments and atypical ERP indicators of cortical activity relative to healthy controls, which may reflect reduced neural resources for information processing, or compensatory processes. OCD is often assumed to be accompanied by greater neuropsychological deficits than other anxiety-related disorders, however a limitation of previous research is that very few previous ERP studies of OCD included anxious control groups. While research into neuropsychological performance in other anxiety conditions is

sparse, there is evidence that executive deficits are also present in panic disorder (Airaksinen, Larsson, & Forsell, 2005). While repetition priming has previously been hypothesised to contribute uniquely to OCD symptoms, our results demonstrate a large overlap between information-processing and neurobiological anomalies between participants with OCD and those with panic disorder and no personal or known family history of OCD, and highlight the necessity of including clinical comparison groups to reliably delineate OCD-specific phenomena. Our results also provide further support for neurobiological and information-processing differences between OCD symptom subgroups, and highlight some OCD-specific phenomena which deserve further investigation.

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Legend of tables

Fig. 1. Example stimulus train. Only the stimuli shown in black are considered in this study.

Fig. 2. Mean RT (ms) to Go stimuli as a function of repetition within trains (G-GGGG, where G is the first Go stimulus in a train and GGGG is the fourth), Group and OCD subgroup (Washers versus non-washers/ checkers). Error bars show standard errors.

Fig. 3. Grand mean waveforms to baseline stimuli by Group. Note: tick marks on the x-axis equal 100 ms; stimulus onset is indicated by the vertical bar on the Cz plot.

Fig. 4. Mean ERP amplitudes for Group effects and interactions to baseline stimuli. P1 amplitude by Group: Top left; N1 amplitude by Group: Top right; N2 amplitude by Sagittal plane and Group: Bottom left; P3 amplitude by Sagittal plane and group: Bottom right. Error bars show standard errors.

Fig. 5. Grand average ERP waveforms at midline electrodes to Go stimulus repetitions by Group. Note: tick marks on the x-axis equal 100 ms; stimulus onset is indicated by the vertical bar on the Cz plot.

Fig. 6. N1 latency to Go stimuli as a function of repetition, by Group. Error bars show standard errors.

Fig. 7. Mean ERP amplitudes for Group effects and interactions to Go stimuli. P2 amplitude by Group and OCD subgroup: Top left; P2 amplitude by Sagittal plane: Top right; N2 amplitude by Sagittal plane by Group: Bottom left; N2 amplitude by Lateral plane: Bottom right. Error bars show standard errors.

Figure 1

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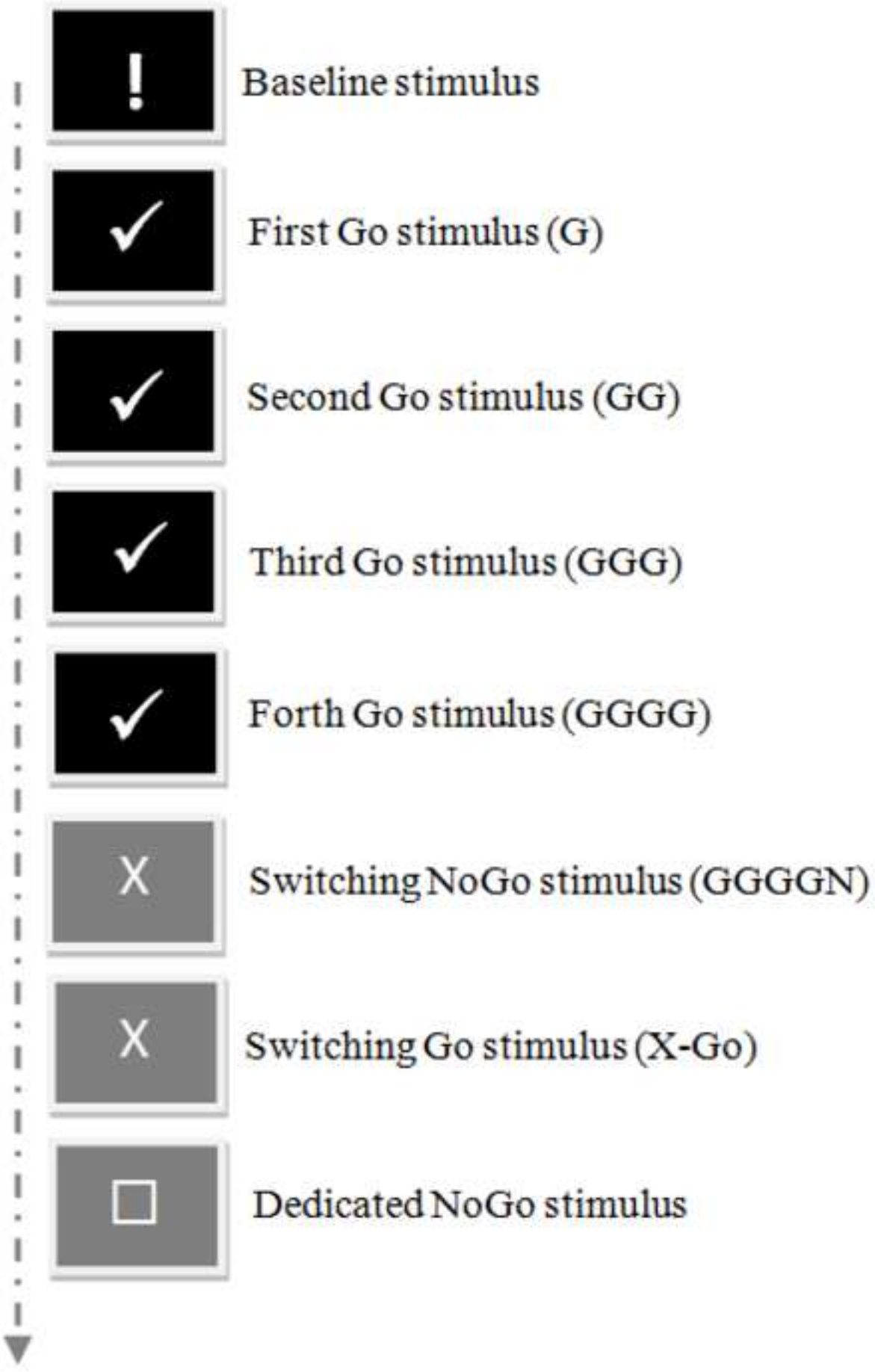

Figure 2

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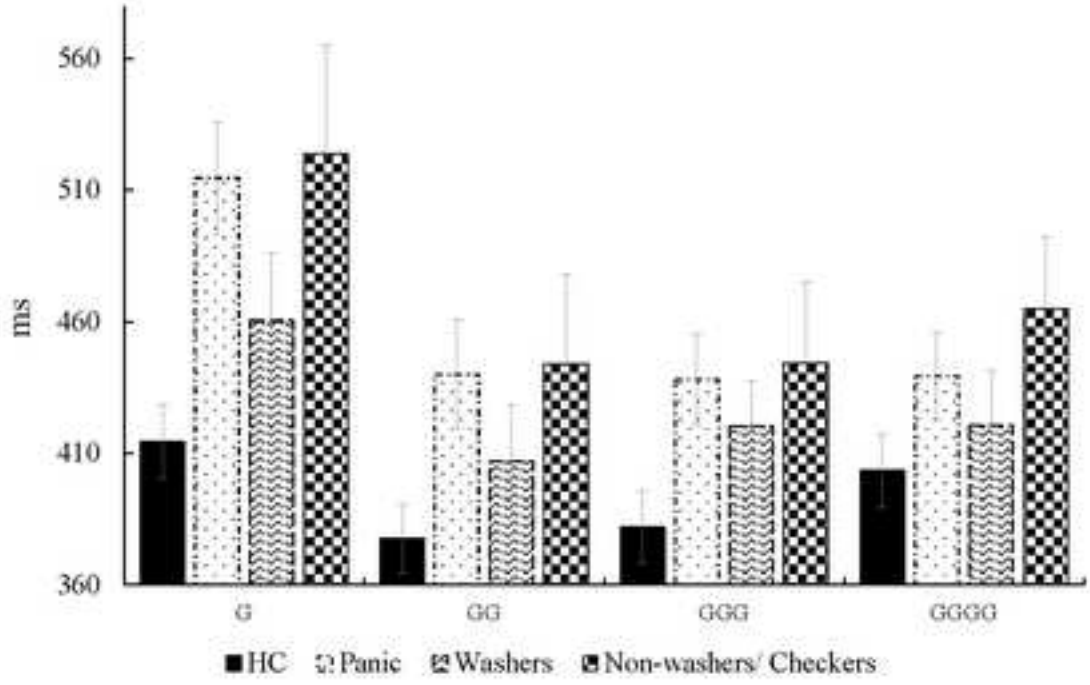

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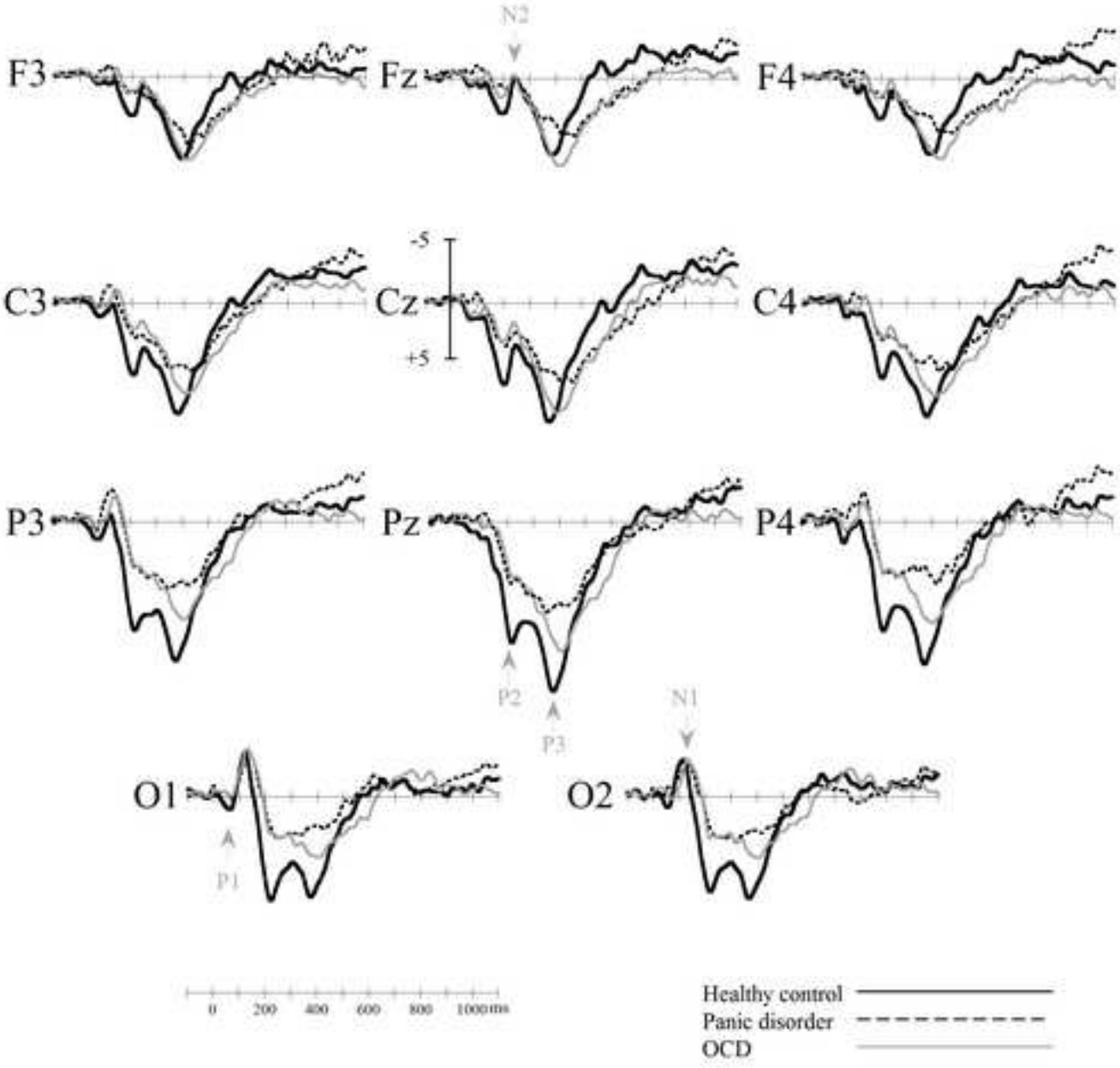

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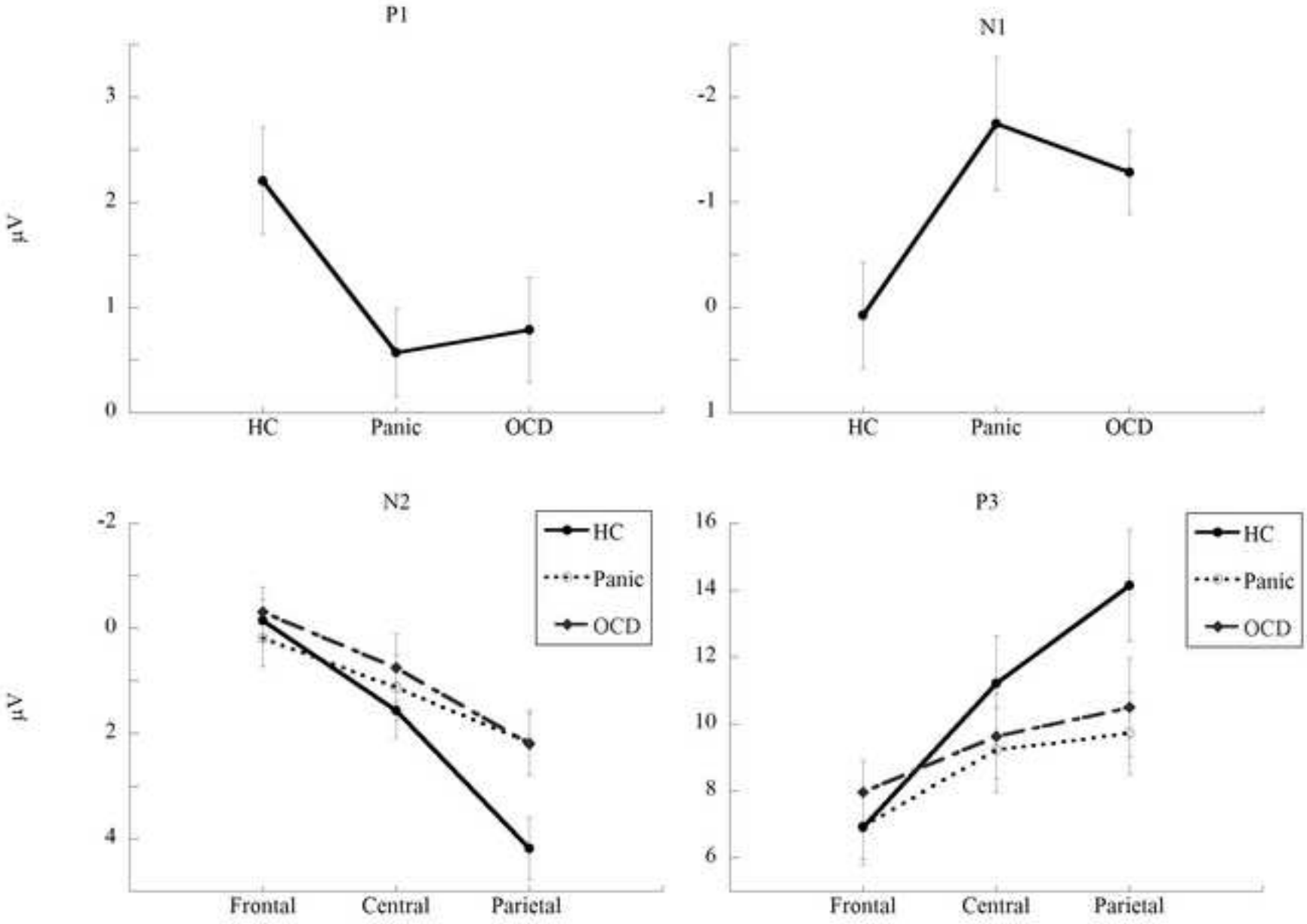

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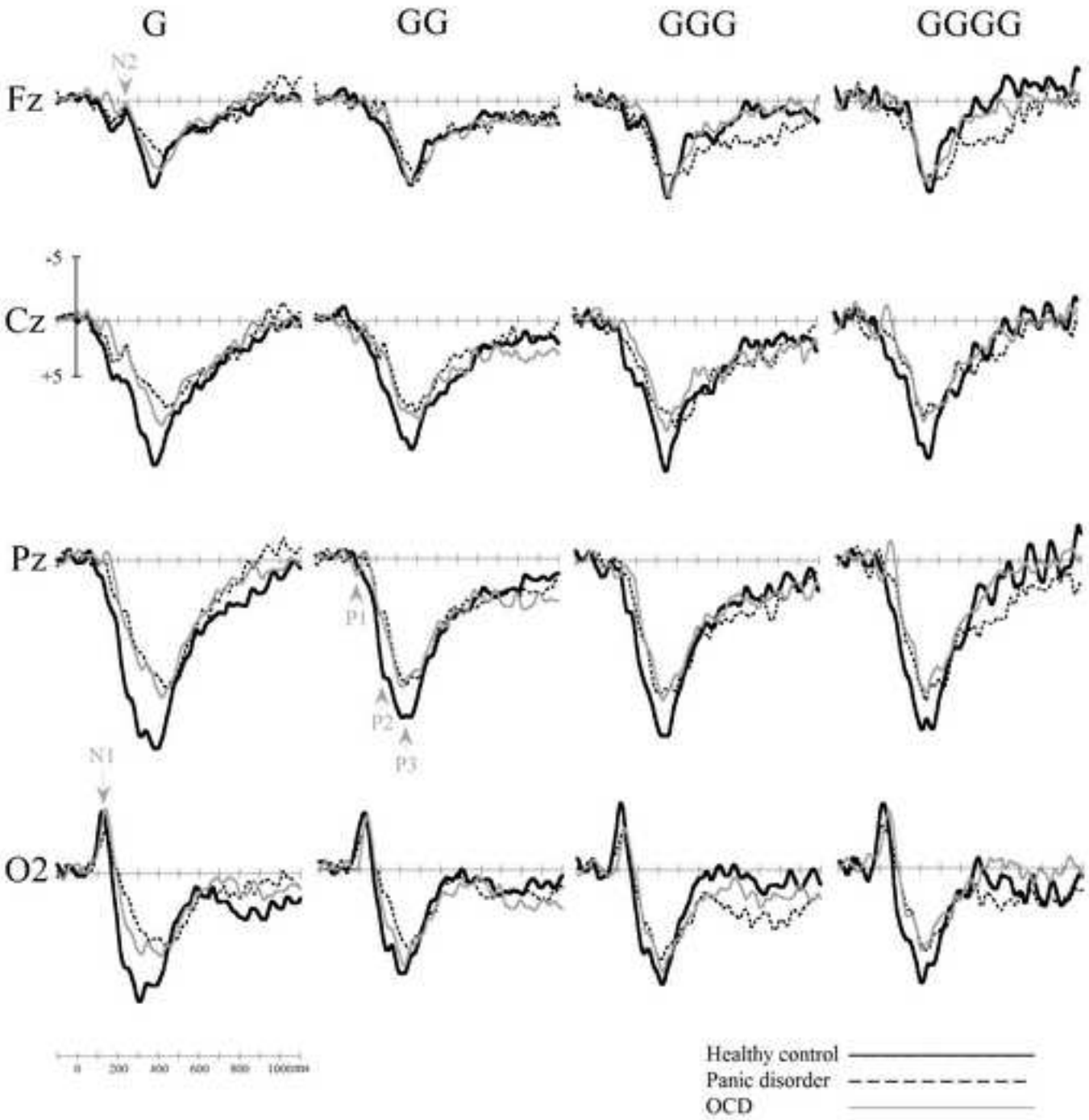

Figure 6

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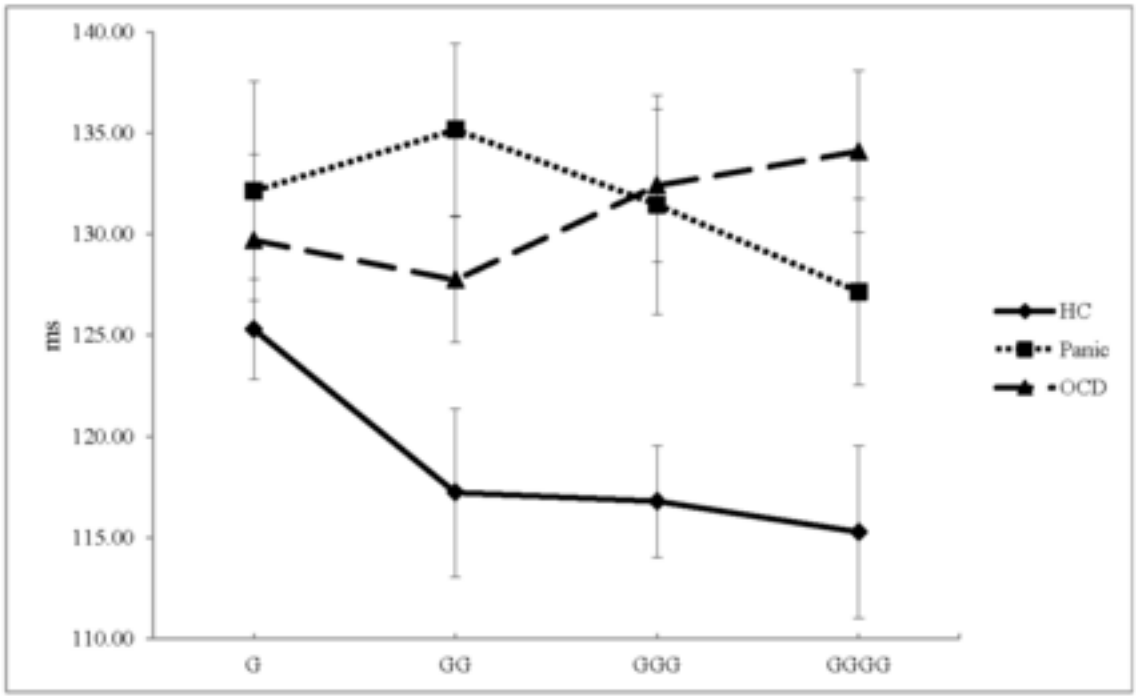

Figure 7

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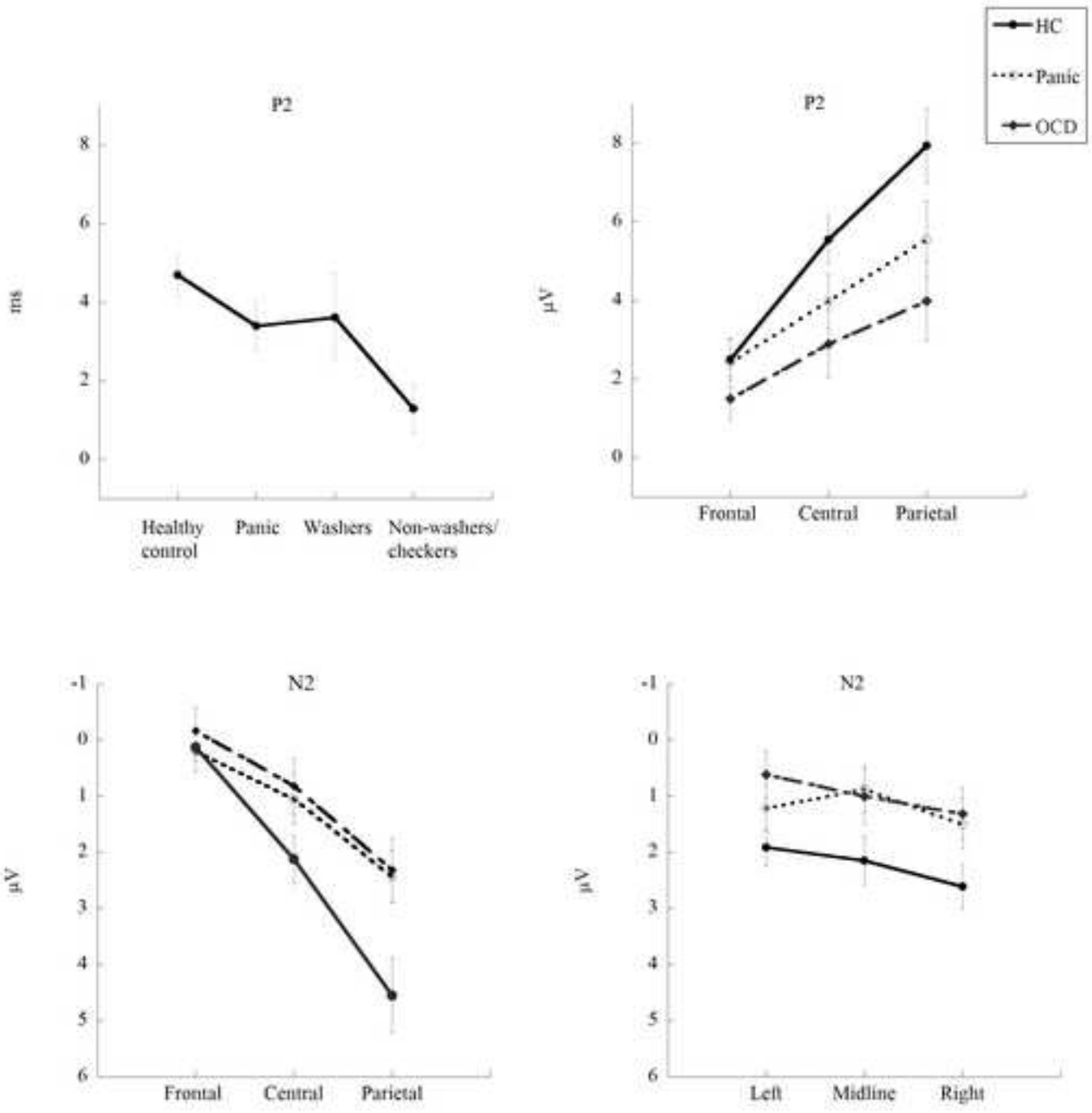

Table 1

Table 1. Participant characteristics and scores in psychometric questionnaires.

Variable		HC (*n* = 20)	Panic disorder (*n* = 20)	OCD (*n* = 20)	Washers (n = 10)	Non-washers/ checkers (n = 10)	OCD vs. HC	OCD vs. panic disorder	Panic disorder vs. HC	Washers vs. Non-washers/ checkers
		N (%)	**N (%)**	**N (%)**	**N (%)**	**N (%)**	-	-	-	-
Gender	Females	13 (65)	17 (70)	11 (55)	5 (50)	6 (60)	*Ns*	*Ns*	*Ns*	Ns
Handedness	Right	18 (90)	17 (85)	16 (80)	9 (90)	7 (70)	*Ns*	*Ns*	*Ns*	*Ns*
	Left	2 (10)	3 (15)	4 (20)	1 (10)	3 (30)				
Medication	On psychotropic medication	-	10 (50)	12 (60)	6	7	***	*Ns*	***	*Ns*
		M (SD)	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	-	-	-	-
Age		33 (13)	38 (12)	39 (14)	39 (13)	39 (16)	*Ns*	*Ns*	*Ns*	*Ns*
Y-BOCS	Obsessions	-	-	14 (6)	12 (3)	15 (8)	-	-	-	*Ns*
	Compulsions	-	-	12 (6)	11 (4)	13 (8)	-	-	-	*Ns*
	Total	--	-	26 (12)	23 (7)	28 (16)	-	-	-	*Ns*
Brief symptom inventory (BSI)	Depression subscale (DEP)	.59 (1)	1.41 (1)	1.61 (1)	1.7 (1)	1.5 (1)	**	*Ns*	*	*Ns*
	Phobic anxiety (PHOB)	.3 (1)	1.86 (2)	1.57 (1)	1.7 (1)	1.5 (1)	***	*Ns*	***	*Ns*
	Obsessive-Compulsive (OC)	1.01 (1)	1.7 (1)	1.87 (1)	2 (1)	1.8 (1)	*	*Ns*	*Ns*	*Ns*
	Anxiety (ANX)	.53 (1)	1.9 (1)	2.1 (1)	2.2 (1)	2 (1)	***	*Ns*	***	*Ns*
	Global Severity Index (GSI)	.6 (1)	1.46 (1)	1.6 (1)	1.7 (1)	1.5 (1)	**	*Ns*	**	*Ns*
Padua Inventory-WSUR	Total score	13 (11)	20 (14)	49 (33)	55 (36)	42 (30)	***	*******	*Ns*	*Ns*
	Contamination and washing subscale	5 (4)	7 (6)	16 (13)	23 (10)	8 (10)	***	*******	*Ns*	**
	Dressing and grooming	1 (1)	1 (2)	5 (4)	4 (4)	5 (4)	***	*******	*Ns*	*Ns*
	Thoughts of harm	2 (2)	4 (3)	7 (7)	8 (7)	6 (7)	***	*Ns*	*Ns*	*Ns*
	Impulses to harm	1 (3)	3 (2)	5 (7)	5 (7)	5 (7)	*	*Ns*	*Ns*	*Ns*
	Checking	4 (3)	5 (6)	16 (12)	14 (13)	18 (12)	***	**	*Ns*	*Ns*
Obsessional Beliefs Questionnaire (OBQ-44)	Total	133 (43)	170 (56)	195 (53)	215 (40)	174 (59)	***	*Ns*	*Ns*	*Ns*
	Responsibility/ threat	50 (16)	64 (22)	72 (21)	79 (14)	65 (25)	**	*Ns*	*Ns*	*Ns*
	Perfectionism/ certainty	55 (20)	67 (23)	74 (23)	84 (18)	64 (25)	*	*Ns*	*Ns*	*Ns*
	Importance/ control of thoughts	28 (10)	39 (19)	49 (13)	52 (10)	46 (15)	***	*Ns*	*Ns*	*Ns*

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 2

Table 2. Mean RT and percentage of errors by stimulus type and group

Stimulus		Healthy control	Panic disorder	Obsessive-compulsive disorder
G	RT (SD)	414 (66)	515 (95)	492 (112)
	% Errors (SD)	.03 (.11)	.07 (.18)	.03 (.05)
GG	RT (SD)	378 (59)	440 (93)	425 (90)
	% Errors (SD)	.03 (.09)	.02 (.09)	.02 (.02)
GGG	RT (SD)	382 (63)	438 (78)	432 (78)
	% Errors (SD)	.03 (.12)	.03 (.05)	.01 (.12)
GGGG	RT (SD)	403 (63)	439 (74)	443 (78)
	% Errors (SD)	.03 (.10)	.03 (.05)	.01 (.02)
Baseline stimulus	% Errors (SD)	.003(.01)	.003 (.01)	.004 (.01)

Table 3

Table 3: Mean amplitude (μV) and latency (ms) of ERP components in the priming task, by Group and Stimulus type.

		P1			N1			P2			N2			P3		
		Healthy control	Panic disorder	OCD	Healthy control	Panic disorder	OCD	Healthy control	Panic disorder	OCD	Healthy control	Panic disorder	OCD	Healthy control	Panic disorder	OCD
G amplitude	Mean	1.66	0.67	1.10	-1.31	-1.43	-2.70	5.64	3.96	2.74	-0.01	-0.22	0.19	18.01	15.23	14.27
	Std. Error	0.55	0.53	0.41	0.64	0.69	0.70	0.76	0.95	0.89	0.38	0.59	0.46	1.98	2.12	1.90
G latency	Mean	97.56	102.34	93.56	128.91	140.04	136.82	192.97	201.95	201.85	310.20	304.24	303.46	370.51	417.38	414.65
	Std. Error	4.10	4.87	5.22	5.10	5.18	5.64	7.19	6.64	5.81	4.97	6.34	6.54	9.77	16.51	10.15
GG amplitude	Mean	0.77	0.75	1.01	-1.21	-1.56	-1.76	4.58	3.57	3.07	0.54	-0.54	-0.34	17.36	15.12	13.61
	Std. Error	0.38	0.56	0.49	0.76	0.56	0.56	0.75	0.89	0.80	0.30	0.57	0.54	2.00	1.52	1.71
GG latency	Mean	97.46	106.93	100.59	132.81	142.29	137.40	193.94	201.66	199.31	302.09	304.82	306.78	346.88	385.94	369.73
	Std. Error	4.41	3.91	3.33	5.32	4.82	4.89	7.61	6.62	4.54	5.95	4.70	6.92	7.55	17.04	14.34
GGG amplitude	Mean	0.70	1.57	1.80	-2.35	-1.98	-2.50	5.35	3.77	3.28	-0.31	-0.23	-0.51	18.55	14.39	13.33
	Std. Error	0.54	0.64	0.60	0.85	0.80	0.60	0.76	0.74	0.89	0.34	0.48	0.42	1.96	1.53	1.56
GGG latency	Mean	87.50	97.95	90.04	121.29	130.86	132.32	190.82	199.61	195.80	302.48	298.48	300.43	343.46	374.61	352.74
	Std. Error	3.89	5.36	4.33	5.54	4.61	5.62	6.92	4.80	8.03	5.52	5.69	6.79	9.06	11.08	9.04
GGGG amplitude	Mean	1.57	1.48	1.36	-1.94	-2.54	-2.81	5.61	3.71	1.97	-0.88	-0.72	-0.82	16.76	15.64	13.42
	Std. Error	0.62	0.63	0.64	0.92	0.87	0.82	0.86	0.96	0.90	0.38	0.55	0.62	2.00	1.43	1.74
GGGG latency	Mean	91.51	98.93	98.54	124.02	132.81	141.31	192.09	196.88	186.23	298.48	298.28	300.43	359.57	369.43	369.34
	Std. Error	4.87	5.01	4.11	4.81	5.31	5.43	6.51	6.07	7.41	4.73	6.20	6.85	8.29	11.26	12.45
Baseline amplitude	Mean	2.21	0.57	0.59	-0.60	-2.11	-1.80	6.52	3.63	3.81	-0.53	-0.41	-0.61	16.06	11.78	12.27
	Std. Error	0.51	0.42	0.50	0.55	0.58	0.43	0.85	0.86	0.95	0.47	0.65	0.56	1.80	1.37	1.67
Baseline latency	Mean	90.82	95.02	100.73	123.73	128.92	131.32	201.95	201.47	207.56	312.73	305.70	319.89	377.35	372.46	414.28
	Std. Error	5.15	4.95	3.51	5.33	4.83	4.39	5.25	4.62	6.48	6.04	4.63	7.47	7.80	12.72	9.10